

ACTIVE GALAXIES IN THE XMM/CHANDRA ERA

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ABSTRACT

In this review talk I discuss the important issues of AGN research and how the new generation of X-ray observatories can help to constrain the physics of AGN. I also present a biased list of the new *XMM-Newton* and *Chandra* discoveries and how they have altered our view of AGN. I also present a set of what are the new types of observations that need to be performed to make significant progress in this field.

Key words: Missions: XMM-Newton, Chandra

1. INTRODUCTION

Why are active galaxies interesting in the X-ray? Active galaxies (often abbreviated as AGN, active galactic nuclei) are the most numerous class of extragalactic X-ray source (above a flux limit of $F(x) > 10^{-14}$ ergs cm $^{-2}$ s $^{-1}$). With the extremely sensitive CCD cameras of *XMM-Newton* and *Chandra* they have been detected out to $z \sim 6$ (Vignali et al. 2001), and potentially further. Their intrinsic luminosity covers an extremely wide range from $< 10^{40}$ ergs s $^{-1}$ (Ho et al. 2001) to over 10^{47} ergs s $^{-1}$ (Fabian et al. 1997) with the “X-ray” (0.1-100 keV) band having 0.05-0.3 (all?) of the total energy. The X-rays originate very close to the supermassive black hole (MBH) as shown by the fact that the X-ray band is the most “rapidly” variable of all wavelength bands. The implication is that rapid variability indicates a small intrinsic size and that a small size is associated with the smallest of all emission regions, the black hole itself.

The X-ray band has the only spectral signature that originates close to the MBH itself – the broad “Fe K” line (e.g., Nandra et al. 1997). One of the surprises of the *XMM-Newton* and *Chandra* mission is that the X-ray band is the most efficient way of finding AGN (Figure 1). This is shown by the ease with which X-ray emission is detected in objects that have “normal” optical, UV, IR and radio properties and the very large number of objects per unit solid angle detected by *Chandra* and *XMM-Newton* (more than 1000 deg $^{-2}$, Mushotzky et al. 2000; Hasinger, et al. 2001) which are almost certainly active galaxies compared to optical surveys which find fewer than 100 deg $^{-2}$ (Kennedy et al. 1997)

In addition to “direct” emission from the region of the MBH itself there is significant X-ray radiation from “jets”, both in the plane of sky as seen in the extended X-ray emission from jets and from jets in the line of sight (these objects are called “BLAZARS”) which is evident in the very high luminosities of these gamma-ray bright objects. All types of AGN are luminous X-ray sources: both radio quiet and radio loud, those with broad optical lines and those with narrow lines. In fact the whole veritable zoo of active galaxy names (Bl Lac, Quasar, Seyfert I/II, LINER, NLAGN, BLRG) are luminous X-ray sources. In addition there is X-ray emission from objects which show no indication of activity in any other wavelength band; that is many/most X-ray selected AGN show weak or no optical “peculiarities” (Maiolino et al. 2000).

2. WHAT ARE ACTIVE GALAXIES?

It is almost certain that most active galaxies are powered by the energy released due to accretion onto a MBH, however so far there has been no direct observation of the process of accretion. In addition there may well be other processes at work such as the extraction of the spin energy of the black hole (Wilms et al. 2001) or the effects of magnetic fields. While we believe that most of the energy comes from accretion the exact mechanism which produces X-rays is not known. This lack of knowledge of the physical mechanism or the geometrical relation of the MBH to the X-ray source is one of the prime difficulties in understanding the wealth of available data.

In recent years there has been the accumulation of strong dynamical evidence for MBH from the motions of stars, ionized and cold gas in the nuclear regions of many nearby galaxies (e.g., Kormendy & Gebhardt 2001). It seems as if the mass estimates are accurate to $\sim 2 - 4$ for a sample of over 20 objects. What is peculiar for many of us who have been in the field for years is that all but one of the proven massive black holes are in non-active galaxies, while the whole paradigm for the existence of MBH was driven by the existence of active galaxies! These recent studies have shown that there are strong connections between the spheroidal component of the host galaxy and the MBH, such that the mass of the MBH can be accurately estimated from the velocity of the stars in the spheroid and roughly estimated by the luminosity of the spheroidal component of the galaxy. There appears to be

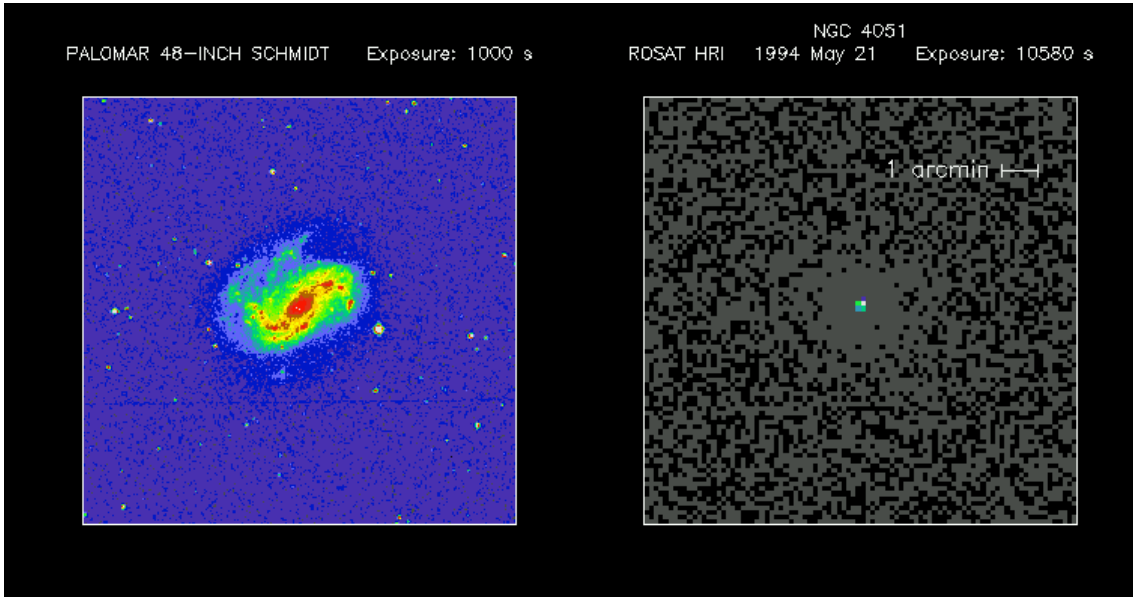


Figure 1. Left Panel: a Digital Sky Survey image of the low luminosity nearby Seyfert I galaxy NGC 4051. Right Panel: a ROSAT HRI observation of the same object. Notice the enormous increase in contrast with the X-ray image and the ease with which the central source is detected.

little relation between the stars or gas in the disk and the mass of the MBH. This is rather interesting since most active galaxies in the local volume of space are spiral systems which do not seem to have a luminous bulge. Since most of the objects are not active at the present time, the mass of the MBH must have been grown much earlier and be strongly connected to how the galaxy forms.

The ratio of the photon luminosity to the mass of the object, the Eddington ratio, ranges from $< 10^{-7}$ to > 1 with some of the lowest values coming from *Chandra* observations of nearby giant elliptical galaxies (Loewenstein et al. 2001). Recent estimates of the mass of black holes in active galaxies is consistent with that in non-active galaxies (Ferrarese et al. 2001) and the new mystery is why so many MBHs are so quiet (e.g. non-active).

It is clear that relativistic effects might be dominant in the X-ray emission and are very important in radio loud AGN. This is shown by the very rapid X-ray variability, the direct connection of radio, X-ray and gamma-ray emission in BLAZARS and the *Chandra* observations of X-ray emission from spatially resolved jets (Sambruna et al. 2001). This direct emission from the jets, shows that, in some sources, a considerable fraction of the total X-ray flux may not come from near the nucleus.

3. WHAT ARE THE FUNDAMENTAL QUESTIONS?

After over 50 years of study of active galaxies and more than 25 years of detailed study in the X-ray band many fundamental questions remain.

1) How do AGN “work” – e.g., how is energy produced/extracted and transformed into radiation. While there has been considerable progress in understanding the physics of accretion and how energy can be extracted from accreting matter, there has been little progress in understanding the process of X-ray photon production or how the energy released in accretion can be transformed into X-ray radiation. It is generally believed that the X-rays in luminous objects are produced by “thermal Compton scattering” (Petrucci et al. 2001) where low energy photons are upscattered into the X-ray band via scattering off of energetic electrons. A detailed analysis of this process in galactic black holes shows that there is great difficulty in understanding the details of the time and spectral variability (Kotov, Churazov, & Gilfanov 2001). Both the physical location of the scatterer and the understanding of how the energy is partitioned into different energy bands are uncertain. It is clear that the X-ray and UV/IR bands have a very complex relationship since the optical/UV band does not vary as rapidly as the X-ray band (Nandra et al. 1998).

2) How is the MBH connected to host galaxy? That is how do MBHs form and effect the galaxy in which they live. Because the mass of the black hole, but not its luminosity is closely related to the stellar properties of the galaxy, the growth and formation of the MBH must be closely related to the formation of the stellar spheroid. Since X-ray surveys find many more AGN than optical surveys and are sensitive to objects embedded in large column densities of material they may be the best way to find MBHs in forming galaxies at high redshift where

other techniques cannot detect AGN because of the effects of redshift and the Lyman- α forest.

3) What is the origin of the wide range of apparent types? The incredible range of radio-IR-optical-UV-X-ray and gamma-ray properties of AGN have produced a zoo of names. While there have been many attempts at unification of objects via geometrical effects (so-called unification models, Antonucci 1993) with a fair degree of success it has become clear that there is a very poor relation between the optical and X-ray properties of objects and thus the whole concept of unification of optically classified objects is called into question. There seems to be some additional property needed: perhaps the effect of star forming regions (Levenson, Weaver, & Heckman 2001), intrinsic weakness of the optical continuum as seen in some nearby LINERS such as M81 (Ho, Filippenko, & Sargent 1996) or the effects of an ionized absorber (Brandt, Fabian, & Pounds 1996) such that high X-ray column densities and low optical reddening and UV absorption are both present.

The apparently fundamental dichotomy between radio bright and radio quiet objects seems to be related to the mass of the MBH, with more massive galaxies, with presumably more massive MBHs having a higher probability of hosting a radio loud AGN (Dunlop et al. 2001).

4) How do they evolve with cosmic time? – It is clear from the faint source counts (Miyaji & Griffiths 2001) and the redshift distribution of the X-ray selected sample (La Franca et al. 2001) that there is strong evolution in luminosity and numbers of X-ray selected active galaxies. Since the number density of low redshift MBHs is much higher than that of AGN this increase in objects and luminosity with cosmic time presumably represents the epoch when these MBH were luminous. The origin of this phenomenon, that is what is actually evolving, and whether these objects are fundamentally different from low z objects is not yet clear.

5) What can we learn about strong gravity? Because the Fe K and perhaps other X-ray spectral features, as well as the continuum, originates from close to the central object there is potential for studying the effects of strong gravity near the black hole (e.g., Miller et al. 2001). There are strong indications from the shape of the Fe K line in many (but not all) Seyfert galaxies and galactic black hole candidates that the effects of special and general relativity are important. It is not yet clear how these features can be unfolded from the unknown geometry of the central regions to learn about strong gravity, but the effects are clearly there. It is also not clear why some objects do not show such Fe K lines, but studies of galactic black hole candidates indicate that the structure of the accretion disk may change drastically with little or no change in source intensity.

6) What is the geometry of the central regions? While we have a general cartoon idea of what the central regions of active galaxies look like, (e.g., Mushotzky, Done, & Pounds 1993) it is not a well tested paradigm. The shape

of, or even the existence of structures like an accretion disk, an obscuring torus or a coronae are not well determined. Without a better understanding of the geometry of these objects much of our data is simply uninterpretable.

4. XMM-Newton AND Chandra

These missions represent a vast improvement in a wide parameter space for observations of AGN:

- a) grasp – that is high collecting area over a broad band-pass
- b) high spectral resolution- with a factor of 100 improvement in energy resolution over *ASCA* and a factor of 100 improvement in collecting area over the previous high resolution spectrometers on *Einstein*
- c) multiwavelength capability- the optical monitor on *XMM-Newton* allows simultaneous measurement of the UV spectrum with a grism, or higher time resolution continuum monitoring for a large number of active galaxies.
- d) angular resolution (with the *Chandra* FWHM $\sim 0.25''$) allowing the first detailed X-ray images of the nuclear regions, precise positions and the measurement of extended small scale emission.
- e) sensitivity allowing detection of sources $\sim 100\times$ fainter than before, as well as an increase in the time resolution and spectral measurement flux threshold.

These properties make the *XMM-Newton/Chandra* combination ideally suited for:

- 1) extending previous studies to fainter, higher redshift, higher and lower luminosity systems
- 2) detailed studies of many bright low redshift objects
- 3) critical progress in the temporal/spectral domain
- 4) building up a complete picture of the multi-wavelength spectrum of active galaxies as a function of redshift, type and luminosity, probing the evolution of quasars over the lifetime of the Universe.
- 5) examining the structure of the central engine in Seyfert galaxies via observations of their broad band X-ray spectrum as well as the multi-wavelength spectral properties and time dependent spectral signatures.

5. EXCITING NEW OBSERVATIONS (A BIASED LIST)

- 1) The existence of narrow absorption lines that are the strongest features in grating observations of Seyfert I galaxies (Kaastra et al. 2000; Kaspi et al. 2001) while the total opacity is dominated by edges. While emission lines are present they are weak. This is to be compared to the optical, IR and UV spectra which are dominated by emission lines. This radical difference between the X-ray and other wavelength bands has not been fully understood yet and indicates the absence of a X-ray “broadline region”. This fundamental difference maybe related to the existence of the classical “two-phase” instability such that the ionization parameter range where the X-ray emitting gas might

exist is unstable, while the optical and UV emitting gas lies in a stable phase (Kinkhabwala et al. 2001).

2) The detection of extended line emission from O VII and Fe K in at least two AGN (NGC 4151, Figures 2,3, Ogle et al. 2000; Circinus, Smith & Wilson 2001) and extended soft X-ray emission regions (NGC 4945, Circinus, etc.) from *Chandra* images. While there had been indications from the lack of variability in the soft flux of many AGN that there could be extended X-ray emission (and a few detections with *ROSAT*), the wealth of detail in the *Chandra* images and the correlation with radio and optical properties is stunning. We now have to understand how this gas is created and the detailed physics of its relationship to the radio and optical emission regions (Yang, Wilson, & Ferruit 2001).

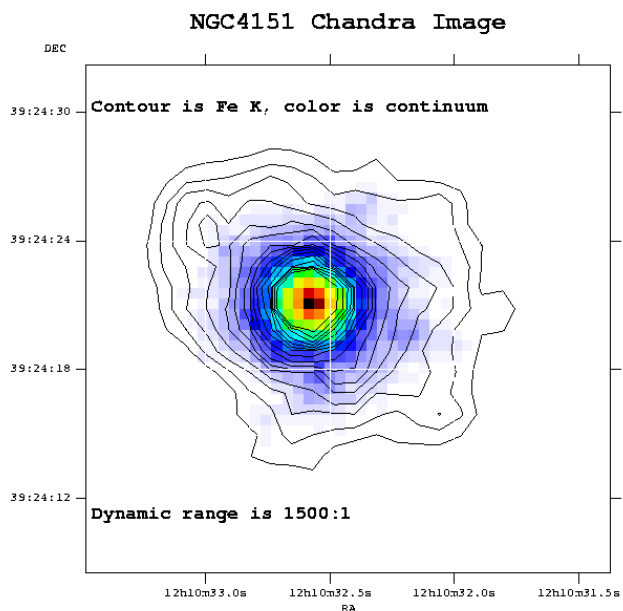


Figure 2. The *Chandra* high resolution image of the continuum in the 3-5 keV band (color) and the Fe K band (6.2-6.8 keV, contour) for the bright Seyfert I galaxy NGC 4151. Notice that both are extended but that the Fe K band seems to be more extended. The very high dynamic range (500:1) allowed by the *Chandra* sharp point spread function is necessary to detect the extended emission. The physical scale is ~ 500 pc/per tic mark.

3) The realization that the Fe K lines are often very complex and are not adequately modeled by the combination of relativistic effects and fluorescence in cold material. *Chandra* data in combination with *ASCA* and *XMM-Newton* data have shown that both narrow lines in combination with broad Fe K lines are common and that ionized Fe K lines are frequently detected. When analyzed appropriately (Yaqoob et al. 2001) the *Chandra* grating observations show the existence of complex Fe K line shapes.

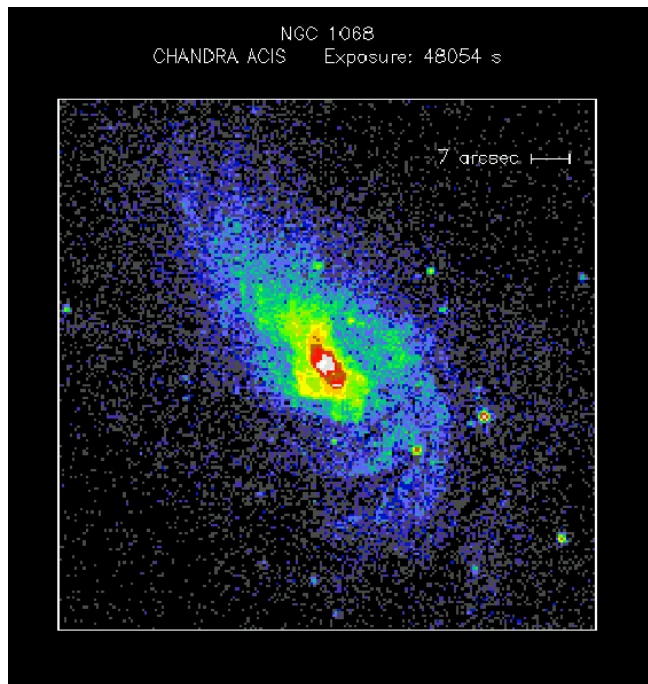


Figure 3. The *Chandra* image of the central 30'' of the nearby Seyfert II galaxy NGC 1068. Notice the very high surface brightness, extended emission from the central regions and the diffuse extended galaxy wide emission. The bright sources to the south-west are most likely ultra-luminous sources in NGC 1068.

While it is still early days it is not yet clear if the narrow Fe K components seen by *Chandra* are part of the broad line profile and/or represent emission from a separate physical region.

4) The proof that Seyfert II galaxies are photoionization dominated – (Sako et al. 2000) as shown in great detail by the *Chandra* and *XMM-Newton* grating observations. However there has not yet been a detailed analysis of the extended emission lines revealed by *Chandra* images and the spatially resolved grating data (for an excellent first step see A. Kinkhabwala et al. this symposium)

5) The realization that the majority of AGN in the universe do not have strong broad optical lines as shown by follow-up analysis of the *XMM-Newton* and *Chandra* deep fields (e.g., Barger et al. 2001). This, in combination with serious difference between optical and X-ray classification schemes (based on *Beppo-SAX*, *XMM-Newton* and *Chandra* serendipitous sources), will make a major change in our understanding of what active galaxies really are, how they evolve and the distribution of energy with frequency.

6) The direct X-ray detection of cold material via resonance M shell absorption in the *XMM-Newton* RGS spectra of several Seyferts (Behar, Sako, & Kahn 2001). This was completely unexpected (the first laboratory detection of such an effect was not until 2001!) and shows the power of X-ray spectroscopy to simultaneously measure

both cold, hot and ionized gas. This unique capability will become more important in the next few years as more detailed comparisons between UV, optical and X-ray spectra are made (Crenshaw & Kraemer 2001).

7) The lack of strong absorption features in BL Lacs from the *XMM-Newton* and *Chandra* gratings. Previous results from *Einstein* and low resolution spectrometers strongly suggested that the X-ray spectra of BL Lac objects had strong absorption features which so far have not been confirmed. This extends to the X-ray band the featureless nature of BL Lac spectra. This also makes them the best objects to use as white light sources for measurement of absorption due to the intergalactic medium.

8) The detection of the first features in the power density spectra of active galaxies with *Rossi-XTE* and the lack of simple correlation between UV and X-ray data (Edelson & Nandra 1999; Pounds et al. 2001). The estimate of a characteristic scale in the time domain at a rather low frequency, similar to that seen in galactic black holes will allow a detailed comparison of these 2 classes of accretion onto black holes. The lack of detailed correlation in the time domain between the x-ray and the UV is challenging to most accepted models of active galaxies.

6. WHAT OBSERVATIONS ARE NEEDED FOR PROGRESS?

As seems clear at this meeting, it is very difficult to organize the vast amount of new information that is being obtained. I believe that we can make more progress if we consider obtaining and analyzing data along the following (non-unique) lines.

1) How do AGN work? What causes the wide range in Eddington ratios? It is evident that there is a very wide range in Eddington ratios for MBHs living in gas rich environments such as our galactic center or the central regions of elliptical galaxies. At present there is little or no understanding of this phenomenon. There may be hope in the detailed study of galactic black hole transients where the X-ray luminosity varies by a factor of over 100,000. Also the recent observations (Komossa 2001; Uttley et al. this symposium) that individual objects can vary by factors of over 100 may give some enlightenment. It is my impression that much of what we think we know about the X-ray properties of active galaxies have been heavily influenced by detailed studies of ~ 30 objects selected as being X-ray bright in the late 1970's. Several of these seem to have changed their properties significantly in the last 30 years giving us some insight into the much larger population of less well studied objects.

Because we now know that most massive galaxies have MBHs one of the fundamental questions is

a) Why are most MBH quiescent at low z ? *Chandra* and *XMM-Newton* observations are able to probe the nuclei of nearby galaxies down to the limit of a normal X-ray binary and it is clear that the nuclei of some galaxies are even dimmer than this limit. The origins of this quiescence

(most clearly seen in the Milky Way and M31) are not known. One possibility is that these objects have a "lifetime", set by unknown physics which is much shorter than the age of the universe. Given the reasonable estimates of the mass of many nearby MBH from scaling relations it is clear that there is a very wide range of Eddington ratios from $L_{Edd} \sim (10^{-7}, 10^{-5})$ found in low luminosity AGN and LINERs and the $L_{Edd} \sim (10^{-3}, 10^{-1})$ in "normal" AGN. In addition to the wide range in Eddington ratios it is clear that the low luminosity objects have unusual other properties. For example (Ptak et al. 1998) most low luminosity objects have less normalized power at high frequencies than normal AGN. Also the high spatial resolution *Chandra* data show that the soft "thermal" like emission components seen in many low luminosity AGN originate from within $1''$ of the nucleus, distinguishing them from more luminous objects. These low luminosity objects also tend not to have strong soft continuum components. Of course, the lowest luminosity of all AGN, NGC 4395, has rather different properties than other low luminosity objects (Moran et al. 2001)

b) Do the X-ray/broad band spectra of these objects match models of low luminosity objects (such as ADAFs)? While there exist excellent sets of time series data for short time scales we need a better understanding of what the parameters coming out of the time series analysis mean and better theoretical modeling of the time series. On long time scales we need much better data with smaller error bars on the longer time series. We also need more well sampled objects, good spectra of objects in "off" state, and a good *theory of time variability*. The differential information coming out of the spectral/temporal domain has proven crucial for understanding galactic black holes and should do the same for AGN. As many people have noticed AGN are actually brighter per unit time scale than galactic black holes and so progress is possible.

c) What is the effect of jets on the broad band spectra and the energetics of these objects? We know that there exist jet dominated sources (BL Lacs/BLAZARS) and that emission from jets is important in several classes of sources (e.g., flat spectrum radio loud AGN). However the importance of jets in general is unknown (e.g., Nagar, Wilson, & Falcke 2001). We need *Chandra* imaging of nearby objects to derive proper samples of objects with significant X-ray emission from spatially resolved jets.

d) What is the origin of the continuum? There is no real detailed theory of the origin of the X-ray continuum in AGN nor do we have guidance for the observational signature of the fundamental physical mechanism other than the energy dependent time lag expected in Compton scattering models. While observers have in general fit simple power laws in the 0.3-50 keV band to the underlying continuum we do not really know its true form. As has been clear for many years the X-ray power law does not extend into the UV band and must steepen at higher energies. We require broad band high S/N spectroscopy with

coverage to higher energies and analysis of simultaneous UV/x-ray data. The cutoff at low frequencies of the X-ray power law is based on the absence of even low amplitude UV variability in concert with X-ray flares.

e) Is there any direct signature of accretion? While we have the paradigm that the luminosity is derived from accretion there is little or no direct evidence for accretion. It is unlikely that we will find such evidence in the optical/UV band because of the presence of many very high S/N spectra with so far no direct signature of accretion. Is there such a signature in the X-ray spectra? There is a claim of highly redshifted absorption in the broad Fe K line in NGC 3516 (Nandra et al. 1999) which might be a possible signature of accretion. This must be tested by high S/N spectroscopy Fe K line spectroscopy, which might only be possible with *Astro-E2*. The early *Chandra* and *XMM-Newton* spectra do not show any evidence for infall in the soft X-ray absorption lines.

2) How are MBHs connected to their galaxy? How do they form and evolve? What are properties of objects with similar mass?

In order to pursue these goals we need to isolate the effects of the Eddington ratio on the X-ray and broad band spectra and compare the properties of objects with similar mass at different redshifts and accretion rates. In order to achieve these goals we need accurate masses of objects with good X-ray data. This is now possible since we know that the masses of the central object scale closely with the velocity dispersion of the stars and that the width of the narrow line region lines scale with the stellar velocity dispersion (Nelson & Whittle 1996).

a) Why do different types of AGN live in different types of galaxies? Is the difference in active galaxy types due to the nature of accretion which is from a hot ISM in elliptical galaxies and a cold ISM in spirals? Is there any relationship between the nature of the local ISM and that the central object?

b) What is the star formation/AGN connection? Many starburst galaxies have a moderately luminous $\log L_X \sim 10^{41-42.5}$ ergs s⁻¹ hard component, which *Chandra* images precisely locate in the nucleus (see Figure 4, *Chandra* image of Arp 220). Is this an AGN, a set of ultra-luminous X-ray binaries or something else? There is clearly a relationship between high column densities in the line of sight and the presence of star formation in many Seyfert IIs. Is the star formation region the high column density absorber? In order to settle these issues we need high S/N RGS and EPIC *XMM-Newton* spectra and time series of absorbed objects with *Chandra* imaging to determine the nature of the absorber and the emitters.

c) What is signature of MBH formation? When and where are the first black holes forming and what is their spectral signature? Can deep *Chandra/XMM-Newton* observations find the “first black holes”, which should be optically blank sources in deep fields (Alexander et al. 2001).

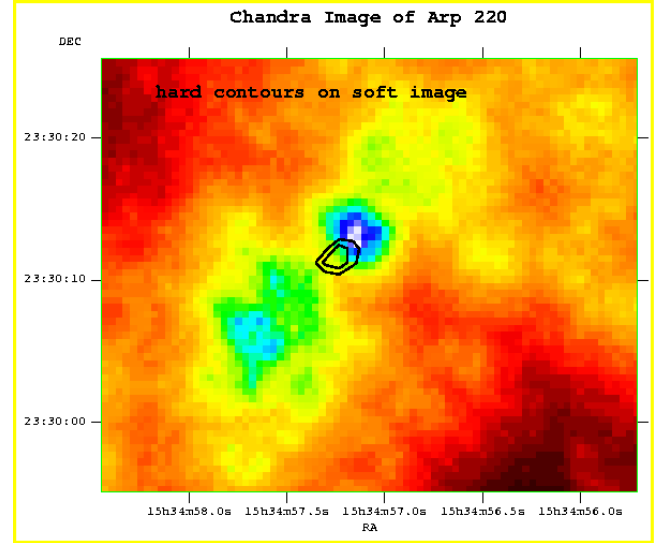


Figure 4. The *Chandra* soft band image (color) and hard band image (contour) of the famous ultra-luminous infrared selected star forming galaxy Arp 220. The extended diffuse emission is almost certainly a superwind generated by the large amount of star formation. The nature of the low luminosity compact hard central source is not clear and could be due to either a low luminosity active nucleus or the sum of X-ray binaries or ultra-luminous sources.

3) What is the origin of the wide range of apparent types; And what causes the difference between them (this is the basis of the *Unified Models*)?

a) What are the true Differences between Seyfert Is and IIs? An X-ray spectral classification system results in different objects than an optical one. In particular there are objects that show large X-ray column densities yet have broad optical lines and there are objects with narrow optical emission lines that do not show evidence for X-ray obscuration (Pappa et al. 2001) What is the connection and how do the unified models need to be modified? We need eigenvector analysis of X-ray/optical/IR samples similar to that recently done by Boroson 2001 for the optical data.

b) What are the X-ray luminous optically “dull” galaxies (Elvis et al. 1981) which make up much of the X-ray background? Are they MBH without an optical signature or something else? Why are the optical lines weak/narrow? What is presence of strong broad optical lines really indicating in optically selected AGN? What are critical X-ray observations?

c) What is the cause of the radio quiet/radio loud dichotomy? Why do some have jets? Is it rapid accretion?, rapidly rotating MBH? Or something else?

The *ASCA/Rossi-XTE* results on radio loud objects show systematic differences in their X-ray spectra, in the frequency of absorption, the strength and shape of the Fe K line and in the X-ray spectral slope (Eracleous, Sam-

bruna, & Mushotzky 2000; Wilkes & Elvis 1987). It also has long been known that radio loud objects are also systematically X-ray bright.

We need much better spectral data; larger samples over a range of radio properties and theoretical models which can provide critical tests of these free parameters. The mystery of radio loud objects is quite fundamental since in these objects the bulk of the emitted energy is in the form of high energy particles rather than radiation and it is only in the X-ray band that there is a noticeable differences in their radiated properties.

d) Early results seem to indicate that more massive BHs are more likely to be radio sources (Dunlop et al. 2001) – what is the X-ray connection?

We need well constructed samples or objects in the radio loudness, BH mass, X-ray properties space.

4) How do AGN evolve with cosmic time and flux? At present we do not know what is actually changing? Is it the accretion rate, spin, mass, age or perhaps some other parameter. The *ASCA* results for relatively bright (and therefore luminous objects) show little evolution in X-ray spectral properties with z . The early *Chandra* results (Vignali et al. 2001) for high redshift objects indicate that the X-ray optical ratios for the high z sample may be smaller by a factor of 2 fainter than the low z objects. However there are subtle issues of bandpass and flux thresholds to take in to account and so it is not clear if there is a real change. If the x-ray to optical ratio is less for the high z objects it might be that the earliest quasars are different than lower z objects and if so we have to search for the origin of the difference. The deep surveys show a different redshift distribution of absorbed vs unabsorbed sources with the absorbed objects being relatively absent at higher redshifts. I believe that some of this is a selection effect since the effects of absorption and reddening becoming much more severe in the rest frame UV than in the optical band. However it is clear that the observed redshift distribution of absorbed objects is lower than that predicted from models of the X-ray background. Absorbed objects at moderate to high redshift may be almost invisible in the optical band and indeed this is seen in the progressive reddening of the faint *Chandra* sources. The general theoretical connection between star formation and AGN activity should be most clear in the X-ray band and seems to have been detected in the *Chandra* stacking data for the HDF-N (Nandra et al. 2002)

a) *XMM-Newton* and *Chandra* deep surveys show a change in the X-ray luminosity and optical characteristics of the source population at low fluxes, indicating that the source counts are dominated by low luminosity spatially resolved galaxies. This indicates that we may have reached the “end” of AGN. It appears that these very faint X-ray objects maybe starforming galaxies as indicated from the strong correlation with ISO sources. (Alexander et al. 2002) One requires large X-ray samples with good spec-

tra at moderate to high z combined with optical galaxy properties to determine the nature of these objects.

5) What can we learn about strong gravity? The Fe K line shape can be a measure of the effects of strong gravity since much of its flux originates from regions very near the black hole. However the line shape is convolved with subtle issues in modeling the continuum. This is natural, since the line can be very broad and the bandpass where the unmodified “power law” continuum can be constrained can be rather small. It is not yet clear what robust results can be obtained and how to separate out relativistic effects from modeling uncertainties on the continuum. At the present time there are only 3 objects with completely unambiguous broad lines; I hope that this number will grow rapidly in the near future.

We do not understand why the line apparently does “not respond” to continuum changes. To quote from a recent study (Weaver, Gelbord, & Yaqoob 2001) [it “The general behavior of the line bears little relation to the continuum ...in no source does the Fe K line simply track the continuum”]. This statement is true on moderate timescales, but has not, been strongly tested with CCD data on the characteristic times in which one expects the line to respond to the continuum, $\sim 10R(G)$ or ~ 5000 s in a moderate luminosity Seyfert galaxy. If indeed the Fe K line does not respond to continuum changes in either shape and/or flux this will make a fundamental change in our understanding of the origin of the line. Preliminary detailed studies of a few objects with *XMM-Newton* (see Fabian, Reeves, and Pounds, these proceedings) shows that the Fe K line does change in flux and shape but the origin of these changes is not known. We need high S/N CCD or better time resolved spectra of the Fe K line. There are only 10 sources in the sky with a high enough line flux that even *XMM-Newton* can derive the line properties on the relevant timescales. We need long observations of these bright sources to characterize the changes in the line. Simple estimates show that even for very variable bright sources > 150 ks observations are necessary.

Are there other X-ray spectral features that show relativistic effects? Given our lack of understanding of the origin of the Fe K lines it is not clear whether one could or could not predict the existence of other lines with the signature of relativistic effects. Thus the possible existence in *XMM-Newton* data of broad lines from ionized O, N, and C is exciting (Branduardi-Raymont et al. 2001). The existence of these lines is at present controversial (Lee et al. 2001) but in this authors opinion seems likely. It is the combination of the broad bandpass and high S/N of the *XMM-Newton* detector combination that made this discovery possible. However the lack of broad emission from Fe L, Mg, Si, or S in this regard is difficult to understand. We clearly need the extension of these recent *XMM-Newton* RGS results to other objects with good signal to noise.

6) What is the geometry of the central regions?

a) Reflection Component? Many authors have interpreted the spectral flattening seen at $E > 7$ keV (e.g., Nandra & Pounds 1994) as an indication of Compton reflection from an accretion disk. However the behavior of the flux of this component with respect to the driving power law has not been easily interpreted as originating in an accretion disk. How do we tell if this radiation is indeed the signature of a disk? I believe that *we need the “quality” of data obtained on galactic black holes* (Gilfanov, Churazov, & Revnivtsev 2001). That is *sensitive* time resolved spectra of variability over a *broad* energy band. While in principle this is possible with a combination of *XMM-Newton* and *Rossi-XTE/Beppo-SAX* so far there are no strong results. Perhaps the more sensitive combination of *Astro-E2* and *INTEGRAL* will be required,

b) What is the warm absorber(WA)? While the WA is an observationally important component of the soft X-ray spectra we still do not know if it is *intrinsically interesting* or just “*in the way*”? By that I mean it is not yet clear if we can learn anything about the nature of the central object, the nature of accretion, or how the MBH gets fueled from observations of the WA. So far we have a vast new knowledge of the warm absorber from *Chandra* and *XMM-Newton* but little “understanding”. It seems as if this gas has a low kinetic velocity and a wide range of ionization indicating that it is low density gas far from the MBH. It has been somewhat of a surprise to see that the velocities are less than that of the broad optical/UV emission lines and similar to that of the UV absorption lines (Crenshaw & Kraemer 2001)

c) Is there a real torus? While schematic models of the central regions postulate the existence of a molecular torus it is not clear what its spectral signature is. The narrow Fe K line seen by *Chandra* and *XMM-Newton* might be this spectral signature but it could also be due to gas in the narrow line or outer broad line region of the AGN or part of the broad line. Higher spectral resolution with better signal to noise with *Astro-E2* and time variability studies will be required. Other crucial information can be obtained from the study of sources that have turned off or undergone large changes in intensity. One might expect that the narrow line will change in intensity on long time scales potentially allowing a mapping of the region of origin (Yaqoob et al. 2001).

d) Can we ever see the accreting material? One of the most fundamental postulates of AGN theory is that the emission is due to accretion, but so far we have no direct evidence. Perhaps we can detect absorption lines of Fe K line with *Astro-E2* indicating infalling gas.

7. GOING BEYOND *XMM-Newton* AND *Chandra*

In the next few years we will have 3 major new missions: *Astro-E2* – which will have high sensitivity, high spectral resolution ($E/dE \sim 700$ at Fe K, ~ 160 at 1 keV), broad band pass (0.3-100 keV) and low background. Its rela-

tively poor point spread functions is not important for studies of bright or luminous AGN if $F(x) > 4 \times 10^{-14}$ ergs $\text{cm}^{-2} \text{s}^{-1}$. I believe that *Astro-E2* will stress detailed Fe K line studies, the connection of the reflector to Fe K line and spectral time domain studies with good resolution. Its studies of the WA may be limited by resolution. *INTEGRAL* – observations will stress the nature of the continuum, whether it has a high energy cutoff, finding “hard” AGN and determining the broad band spectra of BLAZARS

Con-X – will provide detailed spectra of wide variety of objects and Fe K line reverberation at high S/N spectral resolution. There will be many 10’s of objects for which such measurements can be made. The excellent spectral resolution and high sensitivity will increase the samples of objects with detailed by spectroscopy by more than a 1000 compared to *XMM-Newton* and *Chandra*. *Con-X* will extend x-ray spectroscopy to the high redshift universe.

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9. EPILOGUE

It is interesting to compare what we had hoped from *ASCA* with what we actually achieved. I retrieved a list I made before launch in which I had listed the important AGN issues:

1) Fe line shape measurements of Seyfert galaxies – We had hoped to establish the existence of a black hole from determining the detailed Fe line shape and reverberation analysis. This was fundamental, new physics and thus part of the original goals for developing *Astro-D*.

2) Detailed understanding of Seyfert II galaxies – Putting the unified model of AGN on a stronger footing and truly understanding the nature of Seyfert IIs

3) Detailed understanding of the 0.3-2 keV band spectra of Seyfert galaxies – What is the nature of the “soft excess”/WA. Is the soft excess a continuum feature (and thus part of the big blue bump) or are their strong lines due to interesting physics. Again new physics was involved

4) Good spectra of “high z” QSO’s at $E > 2$ keV – Is there evolution in the spectral properties of QSO’s, do QSO’s differ from Seyfert I galaxies ?

5) Understanding the absorption line spectra of Bl Lac Objects – What is the absorption due to, is it variable? Obtain strong bounds on features due to other elements, try to

constrain jet physics (PKS 2155-304)

- 6) X-ray Spectra of jets – Acceleration processes in jets
- 7) Power spectral analysis of variability of Seyfert galaxies at $T < 300$ s – Search for a characteristic length scale
- 8) Detailed X-ray spectra of “low” z qso’s
- 9) X-ray spectra of radio galaxies (BLRG, NLRG’s, FR type I v II) – Nature of unification scheme for Radio loud objects
- 10) the average X-ray spectra of low flux objects and constraints on the X-ray background

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